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Background

Atherosclerotic coronary plaque rupture and subsequent thrombus formation are the main pathophysiologic processes that account for acute myocardial infarction (AMI). Primary percutaneous coronary intervention (PCI) is the contemporary optimal reperfusion therapy for management of AMI, especially in patients presenting with either STEMI (S-T Elevation Myocardial Infarction) or with evolving non-STEMI (NSTEMI) and those requiring rescue intervention post failure of initial administration of thrombolytic agents [1, 2]. A PCI based AMI revascularization reduces the rate of death, stroke and re-infarction when compared with the long standing strategy that relied on select fibrinolytic agents as the first line therapy [3]. However, while many lesions treated by PCI in AMI require only standard balloons and stents, a complex morphology of the offensive plaque, especially with thrombotic content, frequently necessitates a dedicated lesion-specific approach [4]. This calls for utilization of specific devices that provide adequate plaque debulking and thrombus extraction [4, 5] and facilitate resistant-free delivery and precise deployment of intracoronary stents [5–7]. Hence, laser offers a reliable, user-friendly technology which has been successfully applied in select AMI patients. The treatment targets include atherosclerotic and thrombotic plaques, in-stent restenosis and chronic total occlusions occupying infarct related vessels such as coronary arteries and degenerated saphenous vein bypass grafts [8]. When optimal thrombus removal during PCI for AMI mandates

incorporation of mechanical thrombectomy devices [9, 10], the laser energy becomes a valid option as lasers are recognized for their dual capabilities of performing simultaneously precision plaque debulking and thrombus removal [11–13]. Altogether, this chapter aims to provide comprehensive report on the vast experience which had been gained with the use of laser during AMI interventions along the last two decades. It reviews the current criteria for use of the laser, describes the catheter technology, comments on the effective and safe lasing techniques and presents analysis of the results of pivotal clinical laser studies.

The Evolution of Laser Revascularization in AMI

The introduction of laser for PCI in AMI was initially reported in 1993 when a mid-infrared, solid-state, pulse-wave holmium: YAG (2.1 μm wave length) was first used by Eduardo de Marchena and colleagues in three patients at the Jackson Memorial Medical center of the University of Miami, Florida [14]. Another early experience in nine patients who sustained complicated AMI and needed urgent percutaneous intervention was reported by interventionalists from the St. Paul Ramsey hospital of the University of Minnesota [12]. Successful revascularization and excellent clinical outcome were observed in that small series of patients. The issue of proper lasing technique during revascularization for AMI cannot be underestimated. Noteworthy, in the early experience with coronary laser angioplasty, the recommended lasing technique relied upon rapid catheter advancement and continuous energy delivery mode of energy. Over time however, operators began to realize that this method frequently induced vessel and plaque complications. Thus, the technique was subsequently replaced to incorporate slow catheter advancement and intermittent lasing emission [15]. This modification reduced the rate and scope of laser related complications, and, consequently, enabled further exploration of the use of laser [mainly the

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dye, holmium:YAG and xenon chloride] in urgent percutaneous AMI revascularization covering the entire spectrum of acute ischemic coronary syndromes [16, 17]. To date, this technique remains safe and efficacious in coronary and peripheral applications alike.

Noteworthy, both the dye and the Holmium: YAG mid-infrared wavelength lasers were considered reliable revascularization tools [18, 19], however, they are no longer in common use in the US. The ultraviolet 308 nm excimer laser [CVX-300, Spectranetics, Colorado Springs, Colorado, US] thus remains the dominant system wavelength available for cardiovascular interventions in the US and globally. This laser is FDA approved [for physician's discretionary use] in acute coronary syndromes such as unstable angina (Fig. 4.1), the STEMI (Figs. 4.2, 4.3, and 4.4) and the non STEMI type of AMI (Figs. 4.5 and 4.6) [8, 20, 21]. Currently, the excimer laser enables AMI revascularization for targeted thrombus and plaque debulking in native coronary arteries and old saphenous vein grafts alike [8, 20]. Overall, the excimer laser has been shown as an efficient and safe technology for the treatment of challenging, high risk coronary lesions such as left main stenosis, stent restenosis, ostial lesions, arterial and saphenous vein bypass grafts stenoses and chronic total occlusions [21–23]. Noteworthy, this laser is also used for revascularization in acute, chronic and critical peripheral arterial disease with target lesions located in the superficial femoral, popliteal, subclavian and renal arteries [24]. Table 4.1 summarizes the current clinical and angiographic criteria for utilization of laser in the management of AMI.

Technical Characteristics of Cardiovascular Lasers

The pulsed-wave excimer [Xenon Chloride] laser operates at 308 nm wavelength with a pulse duration of 135 ns and output of 200 mJ/pulse. The laser energy is delivered via either over-the-wire or rapid exchange catheters containing flexible optic fibers. The modern laser catheters have improved fiber array with concentric or eccentric tip configuration [25]. Table 4.2 displays the technologic profile of coronary excimer laser catheters which are used in PCI for AMI.

Experiments with Laser- Tissue Effects Pertinent to PCI for AMI

The excimer laser energy interacts with the nonaqueous components of the atherosclerotic plaque [proteins, nucleic acids]. Absorption within atheromatous plaques and thrombotic material results in initiation of photomechanical and photo-thermal processes that lead to vaporization [26]. Laser activation generates acoustic shock waves which mechanically

break and dissolve fibrin fibers, a major constituent of thrombus [27] and considerably suppresses platelet aggregation [28] (Fig. 4.7). A series of in vitro experiments studied the effect of laser emission on thrombolytics, providing strong evidence that laser energy significantly enhances fibrinolysis in fibrin clots initially treated by t-PA. Moreover, despite the known decline in the rate of t-PA induced fibrinolysis with increasing clot age, application of laser energy results in significant enhancement of fibrinolysis [29]. Table 4.3 describes basic research phenomena related to laser activation and their clinical manifestations as pertaining to revascularization in AMI.

Clinical Outcome of Laser Application in AMI

The last two decades led to growing experience with the utilization of excimer laser for revascularization in stable and unstable angina patients who present with a spectrum of hemodynamic conditions, particularly in AMI [32, 33]. Table 4.4 presents the main findings originating from studies of laser application in AMI. It is well established that patients presenting within the first 2–3 h of STEMI commonly exhibit a less complex plaque morphology and smaller thrombus burden compared to patients arriving late; either 5–6 h or even later arrivals such as 12–24 h after the onset of the AMI. Thus, an intriguing practical question arose as to what would be the effect of laser during *every* stage of evolving AMI. Consequently, investigators set forth to explore the laser outcome not only during the early, acute phase of STEMI but also in later phases of AMI. Accordingly, the pivotal, all-comers CARMEL (Cohort of Acute Revascularization in Myocardial Infarction by Excimer Laser) study was launched [21]. The project entailed an investigator sponsored, international, multicenter study enrolling 151 patients in various stages of evolving AMI who were treated in 8 laser experienced facilities in the US, Canada and Germany. While many of the study's patients presented within the first few hours of STEMI, other patients who were late arrivals (later than 6 h after chest pain onset), patients who failed to respond to thrombolytic agents, those with cardiogenic shock (21 %), and infarct related lesions in degenerated saphenous vein grafts (26 %) were intentionally included to ensure maximal clinical challenge for the laser technology. Thus the intention to enroll *every* type of AMI offered real life representation of different clinical scenarios. This approach contrasted considerably with the more restricted, leading studies of PCI in AMI. To complement the study's high standards, the quantitative and statistical analyses were performed by the independent core laboratories of Stanford university, Palo Alto, California and Duke university, Raleigh, North Carolina, respectively. The baseline angiographic left ventriculography demonstrated left ventricular ejection fraction (LVEF) of 44 ± 13 % (normal >55 %). Then a large proportion (74 %) of

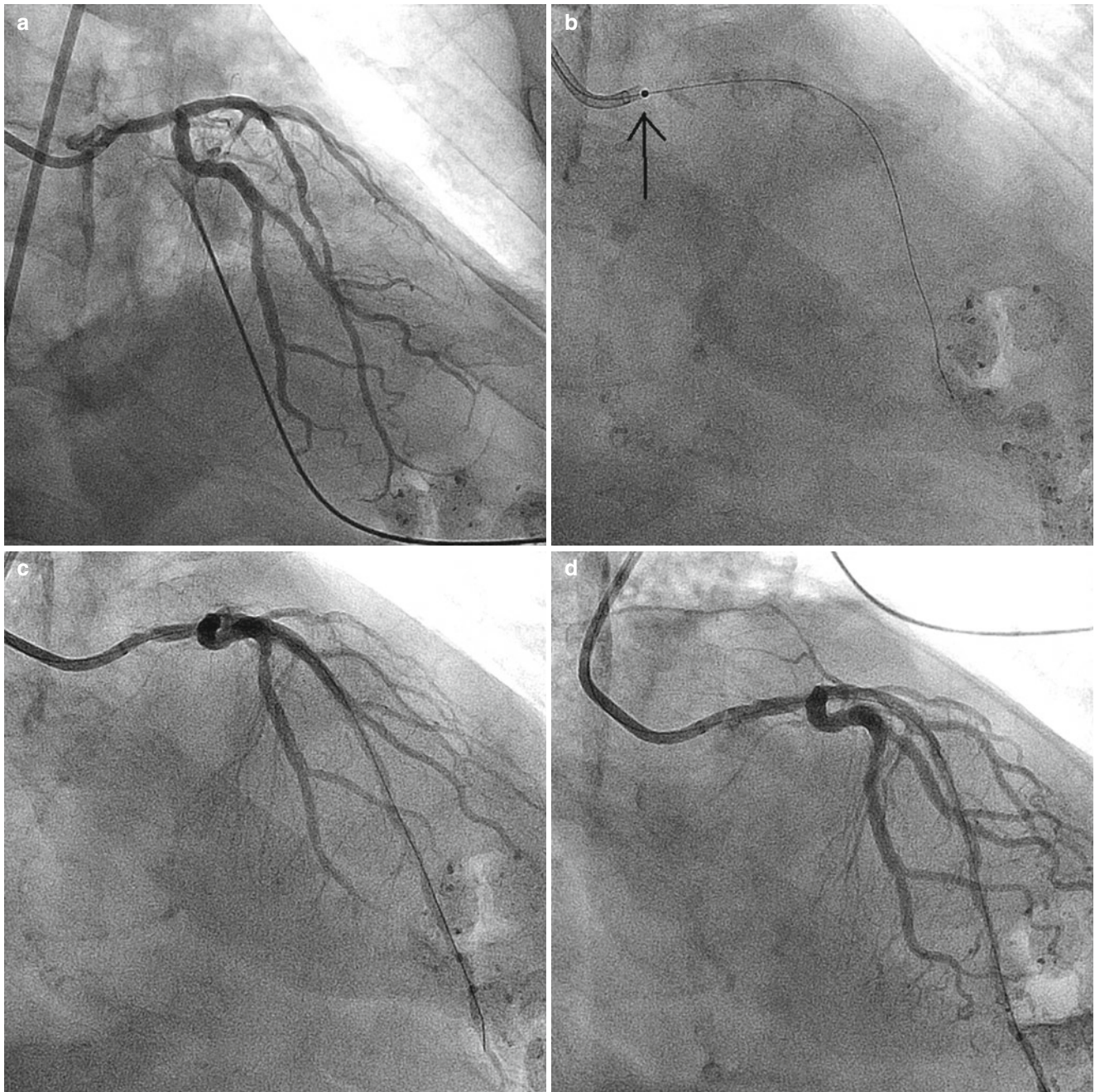


Fig. 4.1 (a) A 90 % eccentric, calcified ostial left main coronary artery stenosis in an 86 year old patient with severe unstable angina and marked anterior-lateral ischemia. The pt. had critical chronic kidney disease receiving permanent dialysis and multiple other medical problems. Surgical approach was deemed too high risk and also rejected by the patient. (b) A 0.9 mm X-80 excimer laser catheter (Spectranetics, Colorado springs, CO) in the ostium of the left main artery before activation. The energy settings were 45 mJ/mm²/25 Hz with antegrade and

retrograde delivery of 250 pulses during intermittent emission and saline flush, totaling of 4 trains. No protection device was used. (c) Selective angiogram demonstrating a smooth recanalization channel as created by the laser. No distal embolization or thrombosis occurred. (d) Angiographic appearance of the left main coronary artery following short balloon inflations and adjunct stenting. The chest pain and ischemia disappeared and the patient was discharged home the next day

of the patients presented critical stenosis of the infarct related vessel (95–100 % stenosis). Specifically, total occlusion (100 % stenosis marked by TIMI 0 flow) was present in 37 % of the patients. These critical occlusions were caused by

plaques with significant thrombus burden, a common finding in many AMI patients [35]. Accordingly, a large thrombus burden-TIMI thrombus grade of 3 or 4 was detected in as many as 65 % of the cases. For the laser revascularization,

small-size catheters (0.9 and 1.4 mm) were the first tool in 34 % of the lesions whereas larger size catheters (1.7 and 2.0 mm) were used initially in 66 %. The final laser catheter size was 2.0 mm in 23 % of the lesions, 1.7 mm in 43 %,

1.4 mm in 25 % and 0.9 mm in 9 %. By visual angiographic assessment the baseline stenosis of 95 ± 6 % was decreased by laser emission to 48 ± 23 % ($p < 0.001$), followed by further decrease as achieved with balloon and stenting, to a final

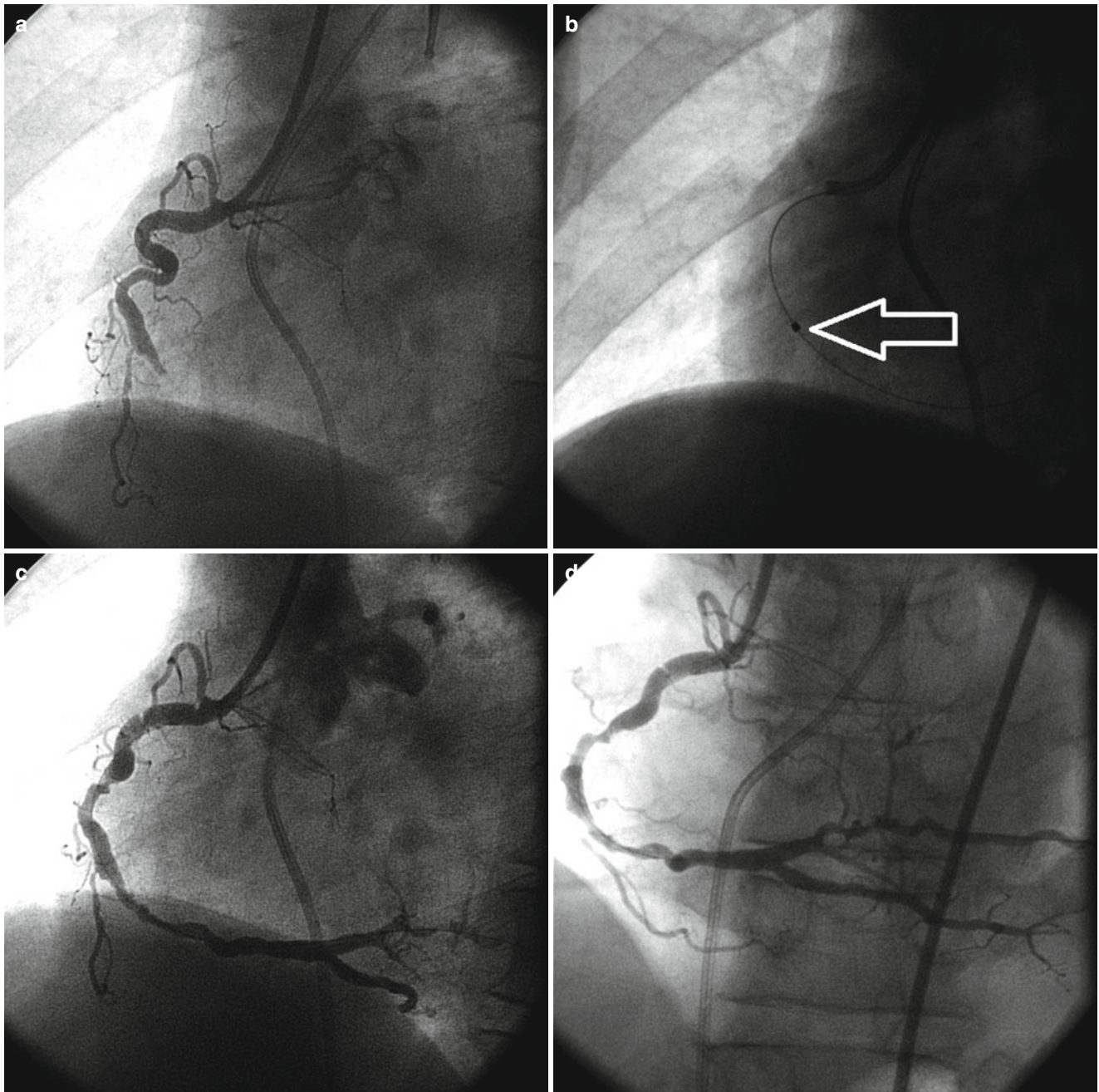


Fig. 4.2 (a) Angiogram from a patient who presented with an Inferior wall ST-elevation myocardial infarction (STEMI). The AMI was caused by a critical atherosclerotic plaque and adherent thrombus which together formed a total occlusion of the distal right coronary artery (RCA). The RCA anatomy is unfavorable for revascularization exhibiting the challenging “Sheppard’s crook” morphology. (b) A 1.7 mm concentric excimer laser catheter (Spectranetics, Colorado Springs, CO) with the catheter’s tip positioned in the occlusion (arrow). This catheter was delivered over a stiff guide wire then activated and

advanced using the slow lasing technique and concomitant saline injections. (c) Angiographic appearance of the infarct-related artery in the left anterior oblique view after completion of laser debulking. Adequate restoration of antegrade flow was observed within less than 2 min from the activation of the laser therapy. (d) The restored antegrade flow demonstrates the posterior descending and the posterior-lateral branches of the RCA. Anterior-posterior angiographic view, (e) Final angiogram showing achievement of the optimal TIMI grade 3 antegrade flow and complete patency of the infarct related vessel and its distal branches

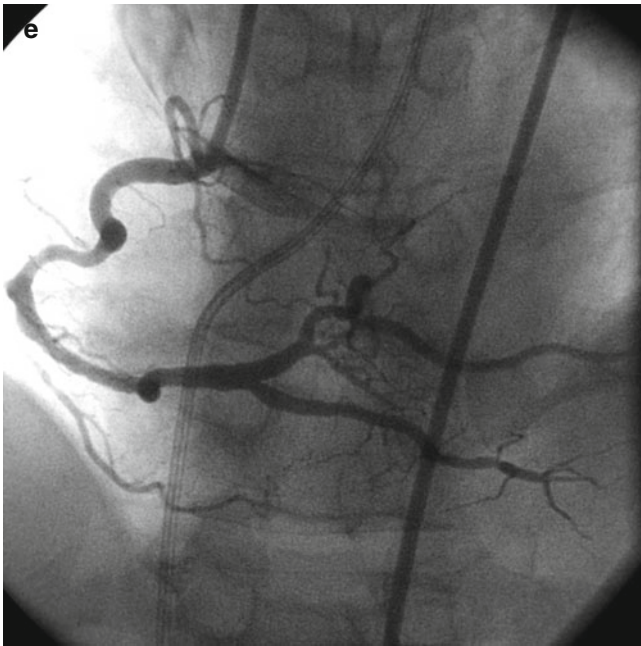


Fig. 4.2 (continued)

of $3 \pm 9\%$ ($p < 0.001$ versus baseline and post laser). The markedly low baseline TIMI flow of 1.2 ± 1.1 increased significantly by the excimer laser to grade 2.8 ± 0.5 ($p < 0.001$), reaching a final post stenting TIMI grade of 3.0 ± 0.2 ($p < 0.001$ vs. baseline). The minimal luminal diameter (MLD) of the treated vessels increased with the application of laser emission from a baseline of 0.5 ± 0.5 to 1.6 ± 0.5 mm (mean \pm SD, $p < 0.001$), reaching a final 2.7 ± 0.6 mm after adjunct stenting (baseline vs. post laser, $p < 0.001$). A 95 % device success, 97 % angiographic success and an overall 91 % procedural success rate were reported. A total of 6 patients (4 %) died, each arrived to the emergency room already in a state of cardiogenic shock. Admittedly, while the study was not powered to examine the role of laser in cardiogenic shock, intriguingly among the 20 patients who presented in this devastating hemodynamic condition there was a relatively low post procedure mortality rate of 30 %, suggesting that the laser might have had a positive impact on survival. The markedly low rate of complications included 0.6 % perforation, 5 % major dissection (all managed successfully with stent), 0.6 % acute closure, 3 % bleeding and 2 % distal embolization. The investigators discovered that the maximal gain in effective removal of the targeted thrombi was directly proportional to the initial angiographic burden, i.e. the larger the thrombotic content, the higher the laser effectiveness. This crucial finding corroborated earlier studies which recorded successful removal of 80 % of the initial thrombotic burden [35].

Overall, the CARMEL study provided the first quantitative sound evidence demonstrating the successful yield of

mechanical thrombectomy devices as applied in PCI for AMI. When further sub-analysis of the study was performed the investigators found that a specific laser related gain was achieved in those who presented later than the optimal 6 h window after AMI onset [34]. Another analysis focused on the challenging sub-group of AMI patients presenting with complete (100 %) occlusion of the infarct related artery. In most of these patients the critical TIMI flow grade 0 was attributed to the combined effect of an underlying plaque and a heavy burden, TIMI grade 5 thrombus. Nevertheless, despite the unfavorable baseline clinical condition and the heavy thrombus load in this selective group, an 89 % laser success rate was achieved as well as 93 % angiographic success and 86 % overall procedural success. Noteworthy, the baseline TIMI 0 flow increased to grade 2.7 ± 0.5 with the laser ($p < 0.001$). Then the final, post stenting TIMI flow was grade 3.0 ± 0.2 ($p < 0.001$ vs. baseline). The rate of complications in this study was considerably low. Distal embolization occurred in only 4 %, a rate serving as a testimony to the reliability of the laser in complex lesions. The “no reflow” phenomenon was detected in 2 %, target vessel dissection in 4 % [lower rate than in standard balloon angioplasty] and perforation occurred in only 0.6 %. The total MACE of 13 % was considered a low rate [37]. Another challenging, high risk sub-group of the CARMEL study patients included 31 subjects whose saphenous vein graft was the infarct related vessel [36]. Unsurprisingly, 39 % of these patients exhibited total occlusion of the old graft (TIMI 0 flow) and 23 % had sub-total (95–99 %) stenosis. Despite the morphologic and thrombotic challenge, the laser was able to increase the minimal luminal diameter in these vessels from a baseline of 0.6 ± 0.6 to 1.6 ± 0.5 mm and facilitated stent deployment resulting in a final MLD of 2.8 ± 0.6 mm. Overall, the laser success rate in this group was 87 % and only 3 (10 %) patients sustained a MACE, a rate considered low for acute interventions in such degenerated target vessels. Notably, there was no case of distal embolization and in only 3 % of the patients, a transient “no reflow” phenomenon occurred. This was achieved without insertion of distal protection devices during the laser interventions. Thus, the unique ability of the excimer laser to concomitantly debulke the plaque, suppress platelet aggregation and vaporize thrombus is unmistakable, serving as a considerable asset in the challenging context of revascularization for AMI. Table 4.5 depicts the excimer laser effect on thrombus laden lesions in AMI.

Lasering Technique in AMI Intervention

Routine patient preparation and anticoagulation for PCI are required. With the commonly used excimer laser the energy settings include a fluence of 45 mJ/mm^2 with 25 Hz. Supporting guiding catheters and guide wires are beneficial in laser proce-

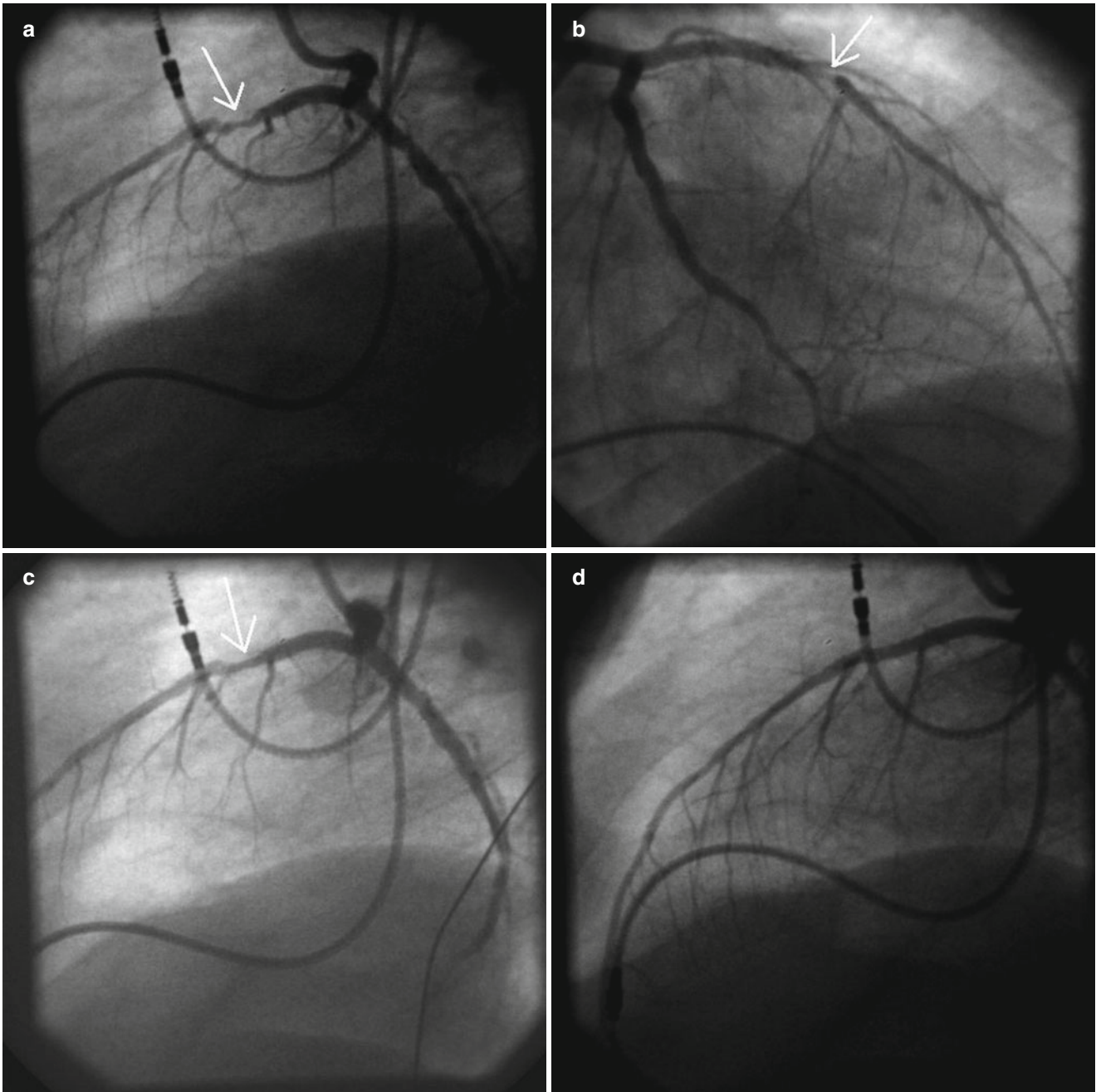


Fig. 4.3 (a) Coronary arteriography in the lateral -caudal projection in a patient who sustained STEMI of the anterior wall. The patient complained of severe chest pain which was accompanied by hemodynamic instability. The Left anterior descending artery (LAD) exhibited a 90 % eccentric lesion with irregular contour located in the proximal-middle segment of the LAD, between two septal perforator branches (*white arrow*). (b) The infarct related vessel and the target stenosis (*white arrow*) in the right anterior oblique view. (c) The target lesion was successfully debulked and adequate post laser channel created within the plaque. The successful debulking incorporated a 0.9 mm X-80 excimer

laser catheter (Spectranetics, Colorado Springs, CO). Activation was performed in a slow (0.2 mm/s) antegrade lasing along the entire length of the lesion, followed by slow debulking retrogradely. Lasing in both directions was combined with saline injections. (d) Final view of the infarct related vessel post stenting in the lateral -caudal view. Complete patency and optimal antegrade flow are present. No distal embolization occurred. (e) final view in the RAO projection. The patient had no further chest pain, the ST segment returned to baseline and hemodynamic stability was observed

dures. Catheter size selection relates inversely to the stenosis severity whereby the greater the stenosis the smaller the initial catheter size [38]. Proper lasing technique is crucial to ensure

success with laser angioplasty [39]. Since the depth of the excimer laser penetration is shallow (35–50 μm) a slow catheter advancement (0.5 mm/s) is recommended. The CVX-300

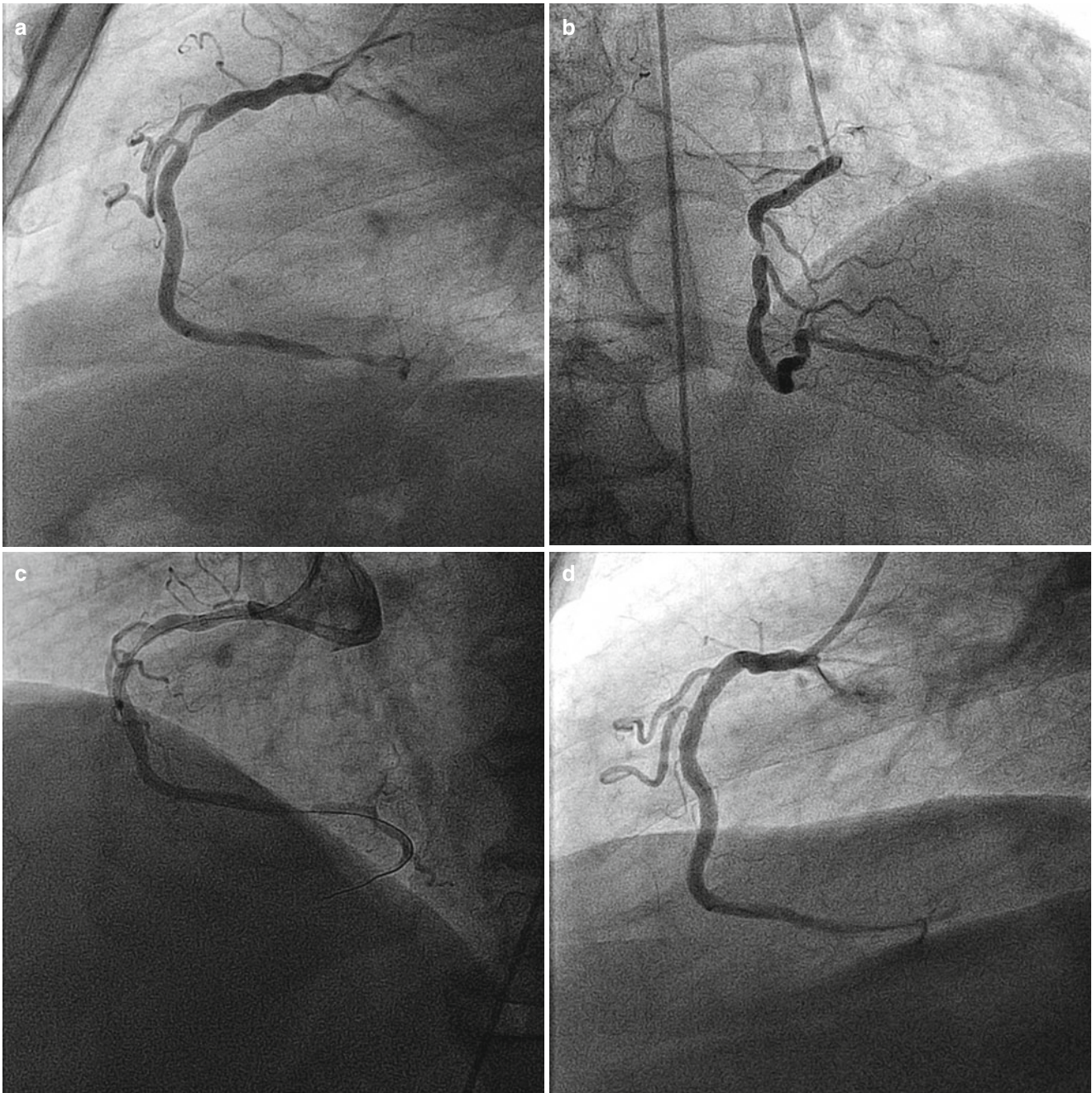


Fig. 4.4 A 59 year old man with inferior-lateral STEMI. Cardiac catheterization performed within 1 h from the onset of chest pain. The pt. had severe chest pain and shortness of breath. (a) the right coronary artery is the infarct related vessel containing a 90–95 % eccentric plaque. Angiogram in the left anterior oblique projection. (b) The right coronary artery in a right anterior oblique view. The marked eccentricity of the lesion is noted. (c) Angiogram post laser application for expedient revascularization of the vessel. A 1.4 COS excimer laser catheter (Spectranetics, Colorado Springs, CO) was used with energy settings of

45 mJ/mm²/25 Hz. The operator incorporated slow (0.2–0.5 mm/s) antegrade and retrograde lasing along the entire length of the lesion. The laser delivered total of 298 pulses. The laser emission debulked adequately the target plaque, thus creating a smooth recanalization channel without any adverse sequela. This channel permitted rapid stent delivery and positioning with optimal deployment. (d) Final angiogram post stenting with a drug eluting stent. The infarct related vessel is markedly open with TIMI 3 flow and no residual stenosis. The chest pain disappeared and patient recovered

console computer limits each lasing train to an interval of 5 s except for the X-80 0.9 mm catheter which is designed for 10 s emissions. Reaching the distal end of the stenosis, the operator may consider slow retrograde [pull back] lasing for maximiz-

ing thrombus removal. Since contrast media significantly amplifies the laser generated acoustic shock waves [40], any contrast in the vessel must be removed prior to laser activation. This step eliminates potential vessel trauma. This is accom-

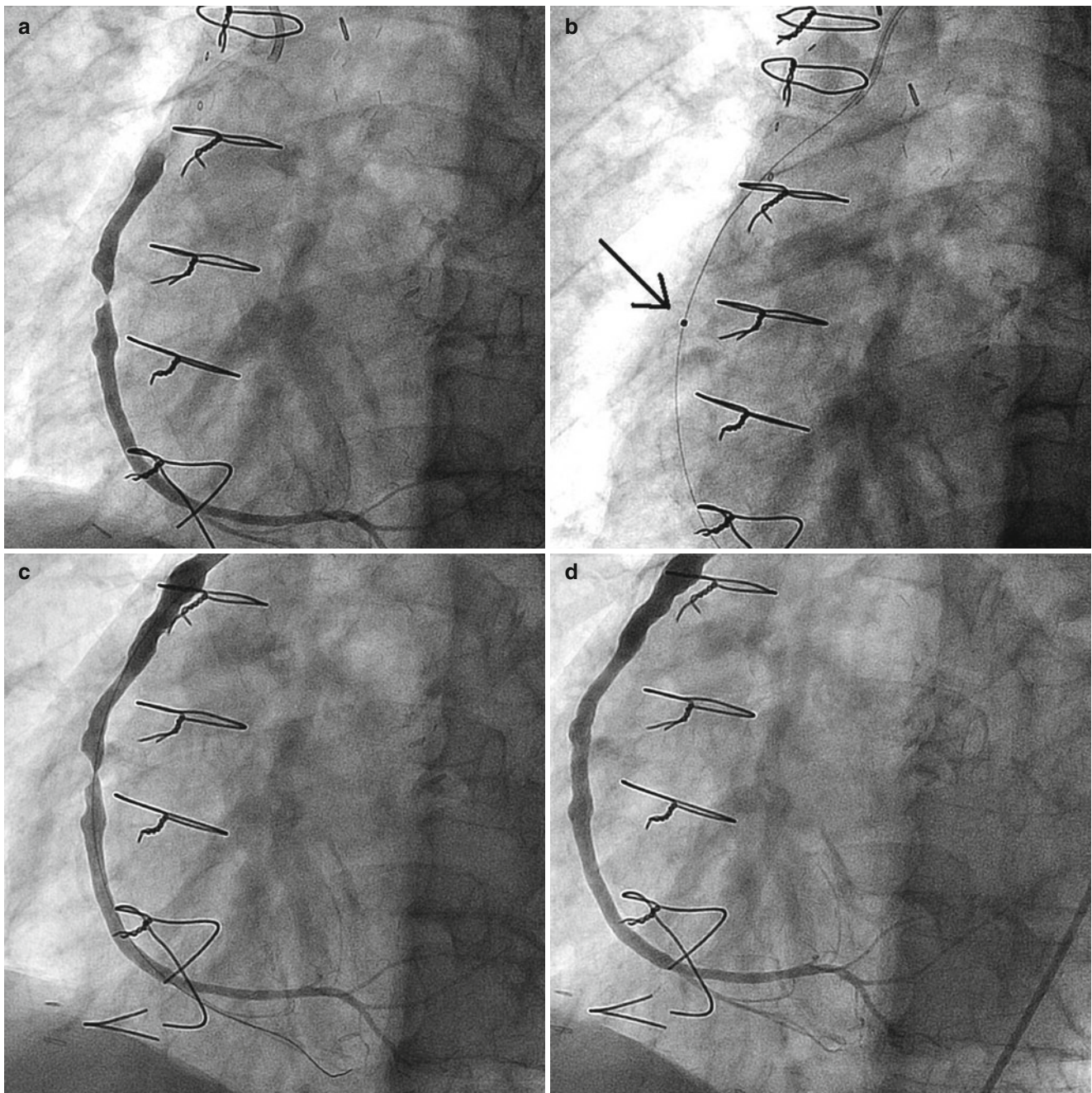


Fig. 4.5 A 70 year old patient with a large size non STEMI accompanied by severe chest pain and ischemia in the inferior-lateral EKG leads. The patient underwent coronary artery bypass surgery twice, 27 and 14 years earlier, respectively. Cardiac catheterization demonstrated total occlusion of the three major native coronary vessels at the aortic origin, thus, the entire cardiac perfusion was dependent on the old bypass grafts. The left internal mammary artery graft to the left anterior descending artery was patent and a saphenous vein bypass graft to the obtuse marginal branch of the circumflex artery was diffusely and severely diseased. (a) A 14 year old saphenous vein graft to the posterior descending artery containing a 99 %, eccentric, thrombotic lesion resulting in a decreased antegrade TIMI 2 flow. (b) The target was treated with a 1.4 mm COS laser catheter (Spectranetics, Colorado Springs, CO) delivering 450 pulses during slow antegrade and retrograde lasing (arrow). Saline injections accompanied deposition of the

laser energy emission. The patient received iv 4000 units of heparin and neither 2b/3a platelet receptor antagonist nor filter protection were used. (c) Angiography immediately post laser application. Adequate debulking of the obstructive plaque is noted. The smooth contour of the residual plaque is a result of the homogeneous distribution of the laser beam. This angiographic appearance is recognized as a unique marker of laser recanalization. The laser utilization achieved immediate cessation of the myocardial ischemia. Excellent flow along the graft and adequate filling of the distal to the anastomosis coronary segment were observed as well. (d) Final appearance of the revascularized old saphenous vein bypass graft post adjunct stenting with a 4.0x18 mm stent. The stent was positioned accurately without any resistant from the residual plaque. No distal embolization or thrombosis occurred. The patient made a complete clinical recovery

plished by initial injection of 10 cc saline into the guiding catheter and then injection of 3–5 cc saline along the intervals of laser advancement. Infrequently, the saline may increase

the Q-T interval and/or ischemia ensues. In such instances decreasing the saline volume to 1–2 cc and ensuring longer pauses between the laser trains are indicated [41]. Laser safety

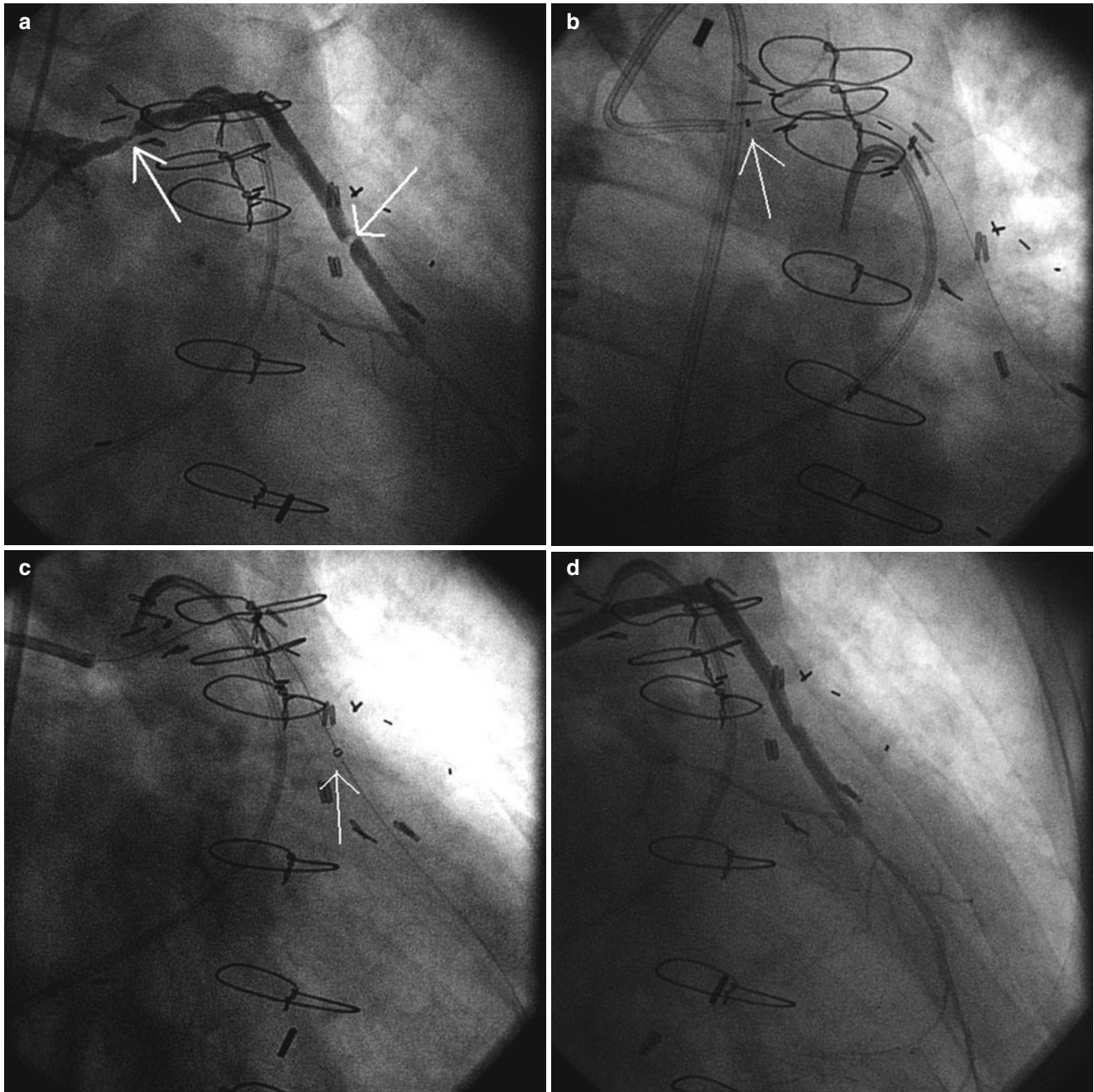


Fig. 4.6 (a) An elderly patient who underwent coronary artery bypass surgery 15 years earlier presented with a large size non STEMI complicated by congestive heart failure and relentless chest pain. Echocardiography demonstrated severely depressed left ventricular ejection fraction. The native coronary vessels were totally occluded and the saphenous vein graft to the LAD was the only remaining vascular conduit. This old bypass graft contained two critical lesions (*white arrows*): proximal 95 % stenosis and middle-distal 99 % eccentric, thrombotic stenosis. The patient had contraindications to the administration of pharmacologic 2b/3a platelets receptor antagonists. (b) A

0.9 mm X-80 COS excimer laser catheter (Spectranetics, Colorado Springs, CO) in the proximal stenosis. Activation was followed by low pressure balloon dilatation and then stenting of the lesion. (c) The same laser catheter was advanced to the distal stenosis. Delivery of laser emission was followed by low pressure balloon dilatation and then stenting. (d) Angiographic appearance of the treated bypass graft following successful laser debulking of both lesions. No filter protection device was used. (e) The final angiographic view of the old saphenous vein graft post stenting. The patient made clinical recovery and was discharged home the next day

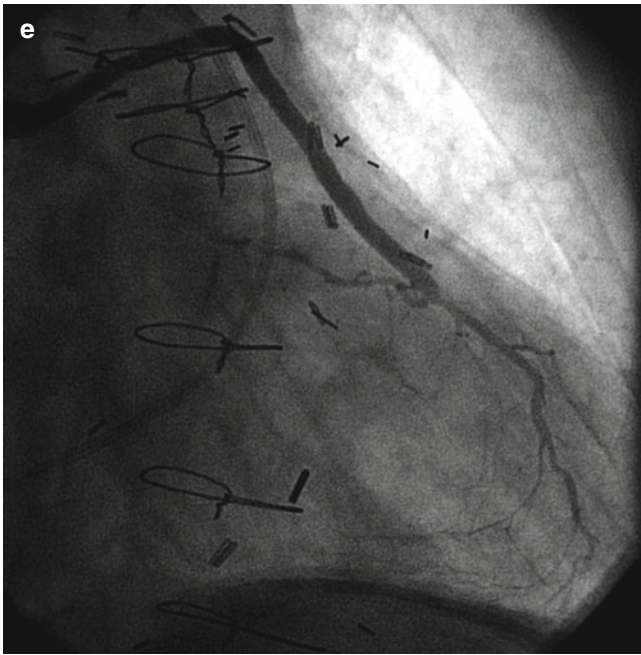


Fig. 4.6 (continued)

Table 4.1 Criteria for utilization of laser in AMI

1. STEMI or non STEMI types of AMI—including late presentation or failed thrombolytic therapy
2. Rescue intervention due to AMI expansion and/or hemodynamic instability
3. Complex lesion morphology in the infarct-related vessel, e.g., heavy plaque burden, eccentric plaque, thrombotic plaque, total occlusion, ostial stenosis, stent restenosis
4. Decreased TIMI flow in the infarct related vessel
5. TIMI Thrombus Grades 2–5—represented by medium-to-extensive thrombus burden
6. Calcified target lesion—containing low-moderate calcium burden
7. Failed thrombus removal by an aspiration catheter
8. Balloon failure to open the infarct-related vessel and/or dilate the target lesion
9. Contraindication for administration of platelet 2b/3a receptor antagonists

is an important component of the intervention and personnel and the patient alike must wear special protective goggles whenever the laser is enabled.

Altogether, based on the abovementioned findings the rationale for using laser in PCI for AMI is summarized as follows:

1. The laser is a user friendly technology which enables rapid preparation and activation for treatment of emergency cardiovascular conditions.
2. The laser offers highly selective absorption within the target plaque and thrombus resulting in expedient plaque debulking and thrombus removal are observed.

3. Laser enhances the effect of pharmacolytics on intracoronary thrombus, even in old, organized or resistant thrombus.
4. Laser induces unique, selective suppression of platelet aggregation kinetics.
5. Laser creates rapid restoration of adequate antegrade coronary flow in the infarct-related vessel.
6. Laser facilitates adjunct stenting.
7. The contemporary coronary laser has an established record of reliability, safety and efficiency as observed in coronary and peripheral interventions.

Complications Associated with the Use of Laser in AMI

As with any other PCI device the laser operators should recognize that it can cause specific complications with serious adverse impact on the targeted lesions, vessels and myocardium and the procedure outcome. These complications include perforation, dissection, spasm, acute closure, thrombosis, distal embolization, “no reflow” phenomenon and failure to achieve the acute revascularization goals. In most instances, complications though relatively rare, mainly relate to mistakes in the operator judgment mistakes and faulty lasing practices [42]. Thus understanding proper lasing techniques and the unique physical characteristics of the laser are imperative for elimination of laser induced complications.

Summary

The laser is a useful technology for application in PCI along each of the various stages of evolving acute myocardial infarctions. The merits of this device are attributed to its reliance upon sound physics principles, the user friendly technology, and, uniquely, the simultaneous ability to vaporize atherosclerotic obstructive plaques, rapidly remove thrombi and suppress platelet aggregation. Due to the precision of the laser debulking emission and the incorporation of slow advancement lasing techniques, the excimer laser does not require placement of adjunct of distal protection devices. Incorporating proper lasing technique is a prerequisite for procedural success including emphasis on slow laser catheter advancement along the target lesion, constant injections of intracoronary saline during laser emission and use intermittent laser debulking mode.

Acknowledgment The authors appreciate the invaluable assistance of Matthew Holtz CVT, RCIS in the preparations of this chapter.

Table 4.2 Coronary excimer laser catheters for PCI in AMI

Laser catheter diameter	Rapid exchange (RX)						
	0.9 mm	0.9 mm X 80	1.4 mm	1.7 mm	1.7 mm E	2.0 mm	2.0 mm E
Vessel size (mm)	≥1.5	≥2.0	≥2.2	≥2.5	≥2.5	≥3.0	≥3.0
Guide wire size	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"/0.018"
Guide catheter compatibility (F)	6	6	6/7	7	7	8	8
Max. tip diameter	0.038"	0.038"	0.057"	0.069"	0.066"	0.080"	0.079"
Max. shaft outer diameter	0.049"	0.049"	0.062"	0.072"	0.072"	0.084"	0.084"
Working catheter's length (cm)	130	130	130	130	130	130	130
Fluence (mJ/mm ²)	30–60	30–80	30–60	30–60	30–60	30–60	30–60
Repetition rate (Hz)	25–40	25–80	25–40	25–40	25–40	25–40	25–40
Laser on/off time (s)	5/10	10/5	5/10	5/10	5/10	5/10	5/10

Fig. 4.7 Effect of in-vitro laser emission on platelet aggregation kinetics. *Upper panel:* the purple curve depicts the normal response to ADP induced aggregation of platelets [control]. With delivery of laser energy, step wise increase in fluence (from the blue to orange and then green curve) results in marked suppression of platelets aggregation, a condition termed the "stunned platelets phenomenon". This unique laser effect is advantageous in clinical applications such as PCI of AMI. *Lower panel:* collagen induced platelet aggregation and the effect of increased laser fluence on the platelets aggregation kinetics (From Topaz et al. [28]. Schattauer GmbH, Publishers for Medicine and Natural Sciences, Stuttgart, Germany. With permission)

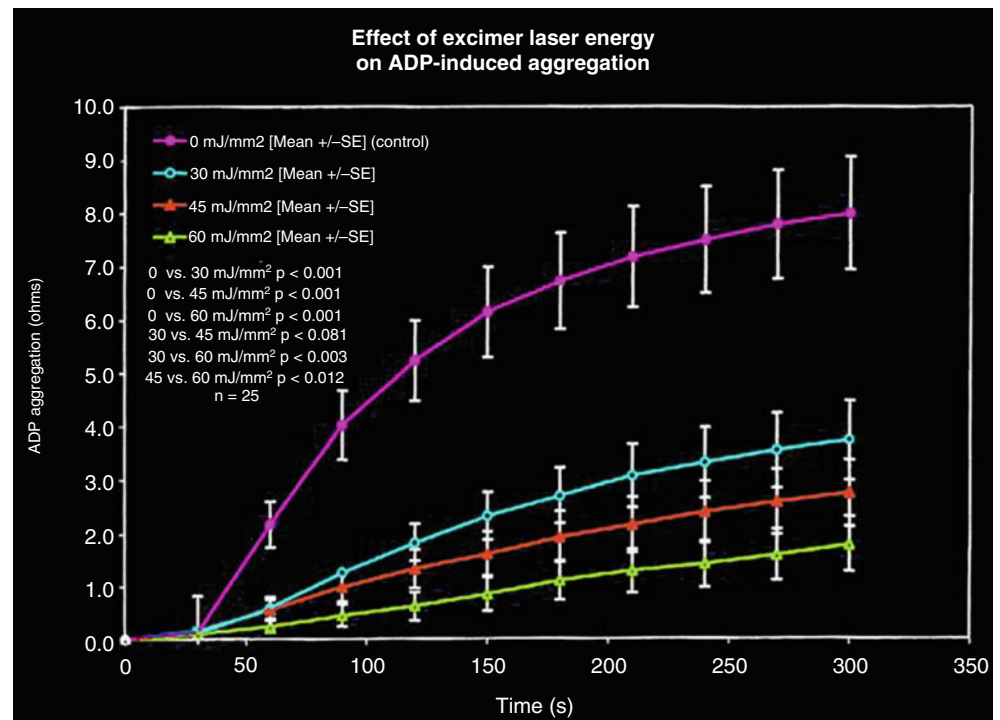


Table 4.3 Correlation of laser induced physical processes with resultant clinical effects in AMI

Process	Laser effect	Reference
Laser irradiation of plaque	No injurious effect on the vessel and plaque	[30]
Absorption in plaque	Vaporization of atherosclerotic material	[31]
Acoustic shock waves formation	Mechanical weakening of the thrombus components	[13, 26]
	Photoacoustic fibrinolytic effect on fibrin in the thrombus	
Thrombolysis	Enhanced action of lytics on old, resistant thrombus	[27, 29]
Laser absorption in platelets	Inhibiting platelet aggregation (“stuffed platelets effect”)	[28]

Table 4.4 Clinical observations—laser application in AMI

	Reference
Feasible and safe for plaque ablation and thrombolysis in complex and complicated AMI	[12]
Laser can be used successfully in AMI patients with depressed left ventricular fraction	[33]
In AMI and unstable angina pectoris, laser efficiently removes 80 % of the targeted thrombus content	[20, 32]
Maximal laser gain in AMI is achieved in infarct-related vessels containing large-to-heavy thrombus burden	[34]
In AMI with continuous chest pain and ischemia: 98 % laser success rate, very low complication rate	[35]
In AMI including STEMI, non-STEMI, late presentation, failed thrombolytic therapy, cardiogenic shock, old SVGs—a 95 % device success is observed	[21]
With laser, unlike most percutaneous devices, thrombus does not adversely impact the procedure outcome	[21, 32]
When degenerated SVG is the infarct-related vessel—no need for insertion of distal protection device	[36]

Table 4.5 Excimer laser effect on thrombus-laden lesions in AMI

Angiographic thrombus size:	Small	Extensive
Pre-laser baseline plaque:		
% DS	76 ± 16	89 ± 15
MLD (mm)	0.7 ± 0.4	0.4 ± 0.5
Laser specific acute gain:		
% DS	25 ± 15	36 ± 20
MLD (mm)	0.8 ± 0.5	1.2 ± 0.7*
Final angiographic results:		
%DS	16 ± 17	22 ± 16
MLD (mm)	3.0 ± 0.6	2.8 ± 0.6

Table based on select data from Topaz et al. [21]

MLD minimal luminal diameter, DS diameter stenosis

*p < 0.03 extensive versus small

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